dropped the cast and grasped the female between the abdomen and thorax, and, moving around from the dorsal surface of the female, deposited the spermatophore in its place upon the genital segment. He then freed the female and made no attempt to renew his hold. In six days the female produced eggs which hatched in seven days.

Despite a great deal of effort, we have never again been able to observe the molt and subsequent copulation, but we have complete evidence that, in three species of two genera (*Harpacticus uniremis, H. gracilis* and *Tachidius littoralis*), the spermatophore is never attached before the female molts, and that, in every case, the male holds the female until she molts. Whenever a normal pair, left a short time before in copula, were found separated, careful examination revealed the cast of the female in the watch glass and a spermatophore attached to the female. In other words, every successful copulation must be prolonged until the female molts.

The longest period in copula observed with a successful issue was between twenty-nine and thirty-nine hours. In two cases the female died in molt, an antenna and a furcal bristle respectively being caught in the cast. In several instances the male, the female, or both died before the molt, probably because of the abnormal conditions of the experiments. In one case the male of a copulating pair was killed and, after the female had molted, another male was introduced, but no copulation took place.

These observations are by no means the first of this character, for there is a general impression among students of Crustacea that ecdysis and copulation or ovulation are closely connected processes. There is evidence that copulation follows a molt of the female in several crabs[2] and in the isopod Gnathia.[3] There is also evidence that ovulation follows the molt in some isopods and amphipods.[4] Finally, Della Valle[5] finds that the male of *Gammarus pungens* holds the female until she molts, assists in freeing her from the cast, and then deposits the sperm.

The males of Amphipoda, Isopoda, *Artemia* and related Phyllopoda, *Limulus,* and of the Copepoda of the group under discussion all have the same habit of carrying or holding the female and all have structures modified for this purpose. Hence, it is possible—it is even probable—that this habit and these structures indicate that, in these forms, the female must molt before fertilization can be accomplished.

Our attempts to find the meaning of this presumably general habit of the Crustacea mentioned have been unsuccessful, but we believe that the softened condition of the shell may be necessary for the attachment of the spermatophore or the extrusion of the eggs.

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[2] See Herrick, F. H., 'American Lobster,' Fish, Comm. Bull., 1895, p. 39. Williamson, H. C., 'Contributions to the Life History of the Edible Crab, *Cancer pagurus*,' Rep. Fish. Board, Scotland, V., 22, 1904. Barnes, E. W., 'Natural History of the Paddler Crab, Callinectes hastatus,' 34th Report Comm. Inland Fisheries of Rhode Island, p. 69, 1904.

[3] Smith, G., 'Metamorphosis and Life History of *Gnathia maxillaris*,' *Mitt. Zool. St. Neapel*, XVI., pp. 469–471, 1904.

[4] Langenbeck, C., 'Formation of the Germ Layers in the Amphipod *Microdentopus gryllotalpa*,' *Jour. Morphology*, XIV., p. 303. See also Korschelt & Heider, 'Text-book of Embryology' (English translation), Vol. II., p. 105.

[5] Della Valle, A., 'Gammarini del Golfes von Napoli,' Fauna and flora des golfes von Neapel, 20, p. 276, 1893.

BLOWING SPRINGS AND WELLS OF GEORGIA, WITH AN EXPLANATION OF THE PHENOMENA [1]

THE blowing springs and wells of Georgia may be divided, for convenience of description, into two classes, namely, those in which the air passes inward for a time and after a short period of quiescence reverses its course, and those in which the quantity of the air is constant and moves in one direction only. One of the best illustrations of the former class of springs is the Grant Blowing Spring, near Chattanooga, Tennessee, a description of which is as follows:

The Grant Blowing Spring is located at the base of Lookout Mountain near the Georgia-Tennessee state line about three miles from the corporate limits of Chattanooga. The

[1] By permission of the state geologist.

spring has long been known and is much frequented by tourists visiting Chattanooga. It may be reached by the Alton Park electric cars, or by the Chattanooga Southern Railway. The proximity of the spring to Chattanooga and its accessibility has doubtless added much to its notoriety.

In general appearance the spring is not unlike many other bold springs met with along the eastern base of Lookout Mountain. It flows from a fissure, at the base of a limestone bluff, forming a good-sized stream. The spring itself reveals but little evidence of the phenomenon for which it is noted. Nevertheless, the phenomenon can readily be detected by holding a smoldering match or lighted paper near the opening from which the water flows. The motion of the air is to be seen in its full force at an opening in the bluff above, about forty feet distant, and at an elevation of ten or fifteen feet above the spring. At this opening, which leads down to the stream supplying the spring, there is, at times, a strong current of air passing inward or outward, depending on the atmospheric conditions hereafter to be discussed. The writer was informed by Mr. W. H. Grant, the present owner of the spring, that the opening above referred to was formerly of sufficient size to admit the body of a man; and furthermore, that he, together with a civil engineer, some years ago entered the opening which led into a cave having large chambers fifteen feet or more in height. The distance to which the cave was explored by Mr. Grant and his companion was not measured, but it was estimated to be nearly a mile. The direction of the cave is said to be southward parallel with Lookout Mountain. Mr. Grant reported that they noticed no current of air in the cave. This, however, may be accounted for by their using a lantern which would not be affected except by a strong draught. The stream forming the spring was found traversing the cave as far as the exploration extended, and many stalactites and stalagmites were reported in the larger chambers.

The formation in which the cave occurs, and from which the spring flows, is one of the lower members of the Carboniferous rocks known as the Bangor limestone. It consists of a very pure heavy-bedded blue or grey limestone attaining a thickness, in the neighborhood of Chattanooga, of about 800 feet. In the immediate vicinity of the blowing spring, the formation dips at a low angle westward toward the axis of Lookout Mountain. The Bangor limestone is highly soluble in meteoric waters and frequently gives rise to limestone sinks and caves of greater or less extent.

At the writer's suggestion, Mr. Grant made a series of observations on the blowing spring in order to determine the time and direction of the air currents, together with the relative temperature of the water flowing from the spring and the outside air. The results of the observations, which extended from December 21 to December 26 inclusive, are embodied in the following table:

TABLE I.

	Time		Temperature		Direction of Current	
Date	A. M.	P. M.	Air	Water	In	Out
Dec. 21	8		46	52	Weak	
21	noon		50	55	Strong	
21		4	48	55	Strong	
22	8		36	54	Strong	
22	noon		42	56	No current	
22		4	46	56		Weak current
23	8		43	56	Strong	
23	noon		42	54	Strong	
23		4	40	56	Strong	
24			27	53	Strong	
24	8		38	54	Strong	
24	noon	4	33	55	Strong	
25			28	52	Strong	
25	8	4	38	56	Not so strong	
25		10	30	55	Strong	
26	4		26	54	Very strong	

The following barometric readings furnished by Mr. L. M. Tindell, officer in charge, U. S. Weather Bureau, Chattanooga, Tenn., show the variations of the atmosphere pressure during the time of Mr. Grant's observations.

The tables here given will be further considered at the end of this paper in the discussion of the explanation of blowing springs and wells.

TABLE II. HOURLY BAROMETRIC READINGS, U. S. WEATHER BUREAU, CHATTANOOGA, TENN., DECEMBER 21 TO 26 INCLUSIVE

Date	21	22	23	24	25	26
1 a. m.	28.85	29.30	29.09	29.35	29.42	29.45
2	.87	.30	.07	.36	.42	.45
3	.90	.30	.06	.34	.42	.45
4	.42	.30	.08	.34	.42	.45
5	.94	.33	.09	.34	.42	.45
6	.97	.33	.13	.35	.43	.45
7	.28	.33	.13	.36	.43	.44
8	29.02	.34	.15	.37	.44	.45
9	.04	.34	.20	.39	.45	.47
10	.05	.34	.2	.39	.44	.47
11	.05	.32	.24	.38	.43	.45
12 m.	.05	.28	.25	.37	.40	.41
1 p. m.	.05	.24	.24	.36	.38	.37
2	.06	.22	.24	.36	.38	.35
3	.08	.22	.26	.36	.38	.34
4	.10	.21	.26	.36	.39	.33
5	.13	.19	.28	.37	.40	.33
6	.18	.19	.29	.40	.42	.33
7	.21	.19	.30	.41	.43	.32
8	.24	.18	.32	.42	.44	.32
9	.25	.15	.33	.44	.45	.32
10	.29	.14	.34	.44	.45	.33
11	.29	.11	.33	.43	.45	.32
12 m.	.29	.06	.33	.42	.45	.32

Boston Well.—The Boston deep well belongs to the second class of blowing wells, namely, wells in which the direction of the air current is in one direction only. Boston, the town in which the well is located, is on the Atlantic Coast Line Railroad, in the southeastern part of Thomas County, twelve miles east of Thomasville. It has an elevation of 198 feet above the sea-level. The surface of the surrounding country is comparatively level, though lime sinks, produced by the subterranean stream, are occasionally met with. The prevailing rock of the region is Vicksburg-Jackson limestone overlain by sands and clays of variable thicknesses.

The well, which is six inches in diameter, has a depth of 290 feet. Water was reported at 120, 160 and 286 feet, respectively. The main water supply at present is said to come from a subterranean stream in the limestone at 120 feet. The casing extends to 110 feet. The static head of the water in the well when completed was 128 feet from the surface, or eight feet below the subterranean stream. Shortly after the completion of the well, Mr. J. Z. Brantley, the mayor of the town, discovered that there was a continuous draught of air passing down the casing, and by placing his ear near the mouth of the well he was able to detect a sound like running water. This indraught, Mr. Brantley reports, was quite strong and continued as long as the well was left open. The writer was unable to verify Mr. Brantley's statement at the time of his visit, owing to the well being connected with the pump which supplies the town with water.

The Lester Well.—This well, reported by William Miller, which is also similar to the Boston well, occurs on B. E. Lester's plantation, twenty miles south of Thomasville, near Iamonia Lake. Mr. Miller, in describing this well, says that at a depth of 154 feet he struck a stream of water running so swiftly that he could not pass a two-pound iron plumb bob attached to a fishing line through it. He reports blowing crevices in the well at 87, 124 and 144 feet. When the well was being bored the air from each of these cavities is said to have passed in in the forenoon and out in the afternoon; but after the completion of the well to the swift moving subterranean stream, the air ceased to pass outward, but was sucked in with a strong steady pull, drawing the flame and smoke of a torch down the casing when held six inches above its opening. This well is cased to 70 feet, below which point it is said to penetrate a soft white limestone.

Causes of Blowing Springs and Wells.—The two classes of blowing springs and wells above described appear to be due to two entirely different causes. Those of the first class, of which the Grant blowing spring is a good type, seem to be due entirely to the difference of atmospheric pressure of the air on the outside and on the inside of the cave.

At the time of my visit to the Grant blowing spring, I was of the opinion that the relative temperatures of the air on the outside and on the inside of the cave, the latter temperature being indicated by the water flowing therefrom, had something to do with the air currents; but the record furnished by Mr. Grant (see Table I.) shows that the direction of the currents has nothing whatever to do with these relative temperatures. That these currents are due solely to the variation of atmospheric pressure appears to be con-

clusively demonstrated by comparing Tables I. and II. The first of these tables shows, with only two exceptions, namely, at noon and 4 P.M. December 22, that at the time when the observations were made there was an ingoing current. Table II., which gives the barometrical readings, shows that the time of recorded ingoing currents, except at noon, December 24, was during the time of increasing atmospheric pressure; and that in the two exceptional cases, which showed outgoing or no currents, the atmospheric pressure was decreasing. In other words, the outgoing currents always take place during rising barometer, and ingoing currents during falling barometer. As the atmospheric pressure usually increases daily from 4 A.M. to 10 A.M. and decreases from 10 A.M. to 4 P.M., it follows that springs, wells and caves of this class will generally have an indraft in the forenoon and an outdraft in the afternoon. If the daily variations of atmospheric pressure were regular, the ingoing and outgoing currents would also be regular and would take place at the same time each day. However, as the daily maximum and minimum barometric readings may vary greatly from day to day, due to approaching storms or other causes, the ingoing and outgoing currents will not always act with the same energy.

In the second class of wells and springs, the constantly outgoing or the constantly ingoing current is entirely independent of atmospheric conditions. The currents, whether outward or inward, act with equal energy during high or low barometer and always move in the same direction. The Boston and the Lester deep wells are excellent examples of wells and springs of this class. The phenomenon which they exhibit seems to be due entirely to the friction of the air on a rapidly moving current of water. This phenomenon is beautifully illustrated in Richard's water air-blast, to be found in many well-equipped chemical laboratories. In the Boston well, and also in the Lester well, appear almost exactly the same conditions met with in Richard's water air blast. The well itself forms the inlet for the air, and the rapidly flowing stream in the subterranean channel below completes the conditions necessary for an ingoing air blast. As the air in the wells here named is constantly drawn in, it naturally follows that it must escape at some other point as an outgoing current, thus giving rise to continuously blowing caves or springs.

As underground streams frequently pass from one bed of rock to another in their subterranean course, they, no doubt, often form waterfalls which possess all the essential conditions necessary for producing an air blast, thus giving rise to continuously blowing caves and springs.

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CURRENT NOTES ON LAND FORMS

GLACIATION OF THE BIG HORN MOUNTAINS, WYOMING

A RECENT report on the 'Geology of the Big Horn mountains' by N. H. Darton (Prof. Paper 51, U. S. Geol. Surv., 1906; excellent plates) describes the range as a wide anticline with steeper dips on the east, eroded sufficiently to expose its granitic core over the broad arching crest, while scalloped ridges of the more resistant members lie along the flanks and in places stretch over toward the axis of the range. R. D. Salisbury presents a chapter on glaciation—in which there is to our view an insufficient recognition of the previous work of F. E. Matthes on the same district—showing that many glaciers occupied the upper valleys during the last glacial epoch. Erosion by these glaciers, working in valleys that had been previously developed by normal preglacial erosion, is held responsible for 'the development of cirques, the cleaning out of the upper parts of the valleys through which the ice passed, the rounding and widening of the valley bottoms, the polishing of the rock surfaces in the valleys and the excavation of some of the lake basins.' The cirques head in superb cliffs, which rise abruptly to the broad highland surface of the unglaciated granite; sharply serrate ridges occur where the widening of neighboring cirques and troughs has consumed the intervening highland surface; here the mountains gain a dis-